Fall 1999

National Environmental Indicator Series

Acid Rain

Environmental indicators are selected key statistics that provide information on significant trends in the environment, natural resource sustainability, and related human activities. The indicators in this bulletin are part of a national set of environmental indicators designed to provide a profile of the state of Canada's environment and measure progress towards sustainable development.

Issue context

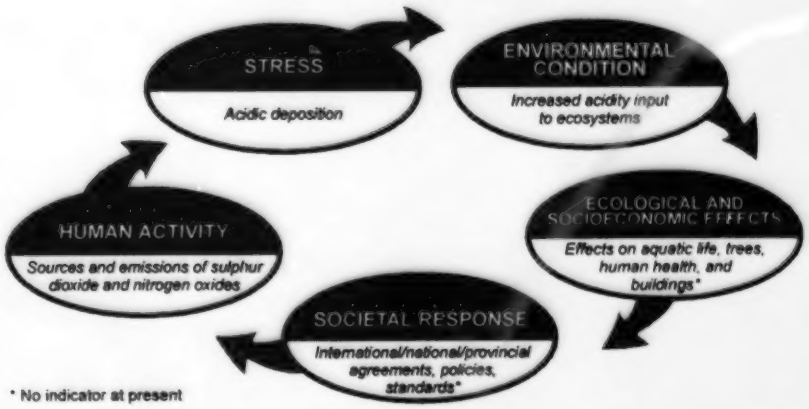
Why is acid rain an issue?

Acid rain became a Canadian environmental issue in the 1970s, after scientists noted losses of fish populations in some highly acidified lakes in northern Ontario. Acid rain is caused by pollutants such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which in the atmosphere are chemically converted to sulphuric acid and nitric acid, respectively. Diluted forms of these acids fall to earth as rain, hail, drizzle, freezing rain, or snow (wet deposition) or are deposited as acid gas or dust (dry deposition). Normal rain is slightly acidic, but acid rain can be as much as 100 times more acidic.

More than 90% of the SO_2 and NO_x emissions occurring in North America come from human activity. The largest Canadian sources of SO_2 are the smelting or refining of sulphur-bearing metal ores and the burning of fossil fuels for energy. NO_x are formed during the combustion of fuels. Transportation (cars, trucks, trains, etc.) accounts for over 50% of Canada's NO_x emissions, power generation contributes 10%, and industrial, commercial, and residential combustion processes combined amount to 30%. Once released into the atmosphere, acidic pollutants may be transported great distances by the prevailing winds and weather systems before being deposited. More than 50% of the acid rain that falls in eastern Canada comes from U.S. sources.

About 4 million square kilometres, or 46% of Canada's total surface area,

What are the links?


STRESS
Acidic deposition
ENVIRONMENTAL CONDITION
Increased acidity input to ecosystems
ECOLOGICAL AND SOCIOECONOMIC EFFECTS
Effects on aquatic life, trees, human health, and buildings*
SOCIETAL RESPONSE
International/national/provincial agreements, policies, standards*
HUMAN ACTIVITY
Sources and emissions of sulphur dioxide and nitrogen oxides

* No indicator at present

are highly sensitive to acid rain. Much of this area is in eastern Canada, which has little ability to neutralize acidic pollutants because of its thin, coarsely textured soil and granitic bedrock, characteristic of the Canadian Shield. This region receives more acidic deposition than any other in Canada. Acid rain is a less serious problem in western Canada because of lower overall exposure to acidic pollutants and a generally less acid-sensitive environment (excluding the Canadian Shield region).

Acidic deposition can contribute to declining growth rates and increased death rates in trees. Instances of dieback and deterioration caused by acid fog and acidic cloud water have been noted in white birch in southeastern New Brunswick and in red spruce in the higher-elevation areas of the eastern United States, respectively.

High levels of sulphate deposition result in the acidification of sensitive lakes, rivers, and streams and cause metals to leach from surrounding soils into the water system. High acidity and elevated levels of metals (notably aluminum) can seriously impair the ability of water bodies to support life, resulting in a decline in species diversity. Recent studies suggest that when lakes acidify and their water becomes more transparent (due to a decrease in dissolved organic carbon), the lakes become more susceptible to harmful ultraviolet-B (UV-B) radiation, which can penetrate more deeply and harm more species. Further research is required to better understand the combined effects of acidic deposition and UV radiation on aquatic ecosystems.

SO_2 and its by-products also cause deterioration in building materials, such as cement, limestone, and sandstone. Some significant historic structures such as the Canadian Parliament Buildings are slowly being eroded by acidic pollutants.

Human exposure to particulate matter, including sulphate and acidic aerosols, leads to increased respiratory problems. Recent research indicates a relationship between decreased lung function, increased cardiorespiratory mortality, and long-term exposure to ambient acidic aerosols.

What is being done?

1985–87: The Canadian Acid Rain Control Program is established. Federal–provincial agreements are signed with the seven eastern provinces to reduce their combined SO_2 emissions to 2.3 million tonnes per year by 1994 (a 40% reduction of the 1980 level).

1991: The Canada–United States Air Quality Agreement is signed to reduce SO_2 and NO_x emissions. Canada is committed to a permanent national limit on SO_2 emissions of 3.2 million tonnes per year by the year 2000 and a 10% reduction in projected NO_x emissions from stationary sources by the same year. The 2.3 million tonne per year limit on SO_2 emissions for eastern Canada is extended to the year 2000.

1994: A Sulphur Oxide Management Area (SOMA) is established in the main source region in eastern Canada. An SO_2 emissions limit for the area is set at 1.75 million tonnes a year beginning in the year 2000.

1997: A report on protecting acid-sensitive ecosystems, human health, and air visibility in Canada, entitled *Towards a National Acid Rain Strategy*, is submitted to the National Air Issues Coordinating Committee (the federal-provincial-territorial body charged with addressing air issues in Canada). The report recommends further SO_2 emission reductions of up to 75% from current commitments in targeted regions of eastern Canada and the United States, to prevent critical loads for acidic deposition from being exceeded across eastern Canada.

1998: A Canada-wide Acid Rain Strategy for Post-2000 is signed by federal and provincial/territorial Ministers of Energy and Environment in October. It provides a framework for further SO_2 emission reduction commitments in eastern Canada beyond 1999.

Acknowledgements

Data and advice provided by the following agencies are gratefully acknowledged:

Canadian Heritage
Parks Canada
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Environmental Protection Service
National Water Research Institute
DOE Regions
Fisheries and Oceans Canada
Ontario Ministry of Environment

For further information, please contact:

Indicators and Assessment Office
Ecosystem Science Directorate
Environmental Conservation Service
Environment Canada
Ottawa, Ontario
K1A 0H3

Facsimile: (819) 994-5738

This bulletin is accessible on Environment Canada's Green Lane Internet site (www1.ec.gc.ca/~soer).

A TECHNICAL SUPPLEMENT TO THIS BULLETIN IS ALSO AVAILABLE.

THIS BULLETIN WILL BE UPDATED PERIODICALLY.

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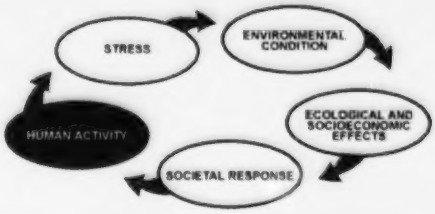
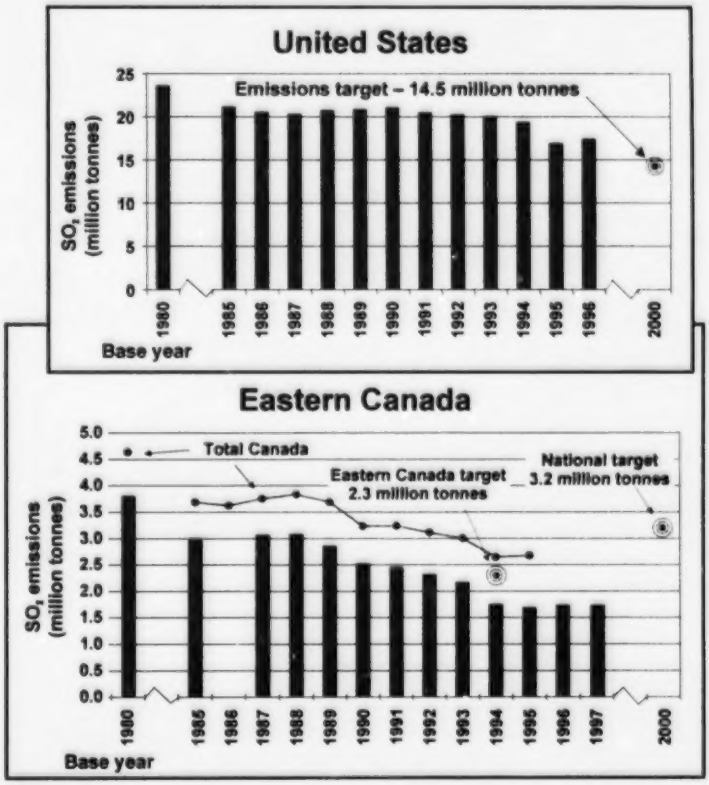


Acid Rain

Indicator: Emissions of sulphur dioxide

- Eastern Canadian emissions of SO_2 remained relatively constant from 1994 to 1997. In 1997, emissions of SO_2 in the seven easternmost provinces remained 24% below the target of 2.3 million tonnes.
- Smelting of metal ores, the largest emission source in Canada, accounted for 49% of total eastern Canadian SO_2 emissions in 1997. Power generation and other sources contributed 21% and 30%, respectively.
- Canada met its goal of limiting annual national SO_2 emissions to 3.2 million tonnes in 1992. By 1995, its SO_2 emissions were down to approximately 2.7 million tonnes, a 42% reduction from the 1980 level of 4.6 million tonnes.
- Total U.S. emissions of SO_2 fell by about 13% between 1993 and 1996, from 19.9 million tonnes to 17.4 million tonnes.
- Electric utilities are the largest source of U.S. SO_2 emissions, accounting for 66% of total emissions in 1996.
- The United States is committed to reducing its annual SO_2 emissions to 14.5 million tonnes by the year 2000, 9.1 million tonnes below 1980 levels.



Notes:

i) Eastern Canadian emissions data for 1986 are unavailable.
ii) U.S. emission estimates (tons) have been converted to tonnes (1 ton = 0.91 tonnes).
iii) Canadian emission estimates are based on Canada's 1998 report to the United Nation Economic Commission for Europe (UNECE). They may differ from previously released estimates because of changes in methodology.

Canadian sources:

Eastern Canadian emissions: Environment Canada. 1990–97. *Annual Report on the Federal–Provincial Agreements for the Eastern Canada Acid Rain Program.*

Total Canadian emissions: Pollution Data Branch, Environmental Protection Service, Environment Canada.

U.S. source:

U.S. Environmental Protection Agency. 1997. *National Air Pollutant Emission Trends, 1990–1996.* Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

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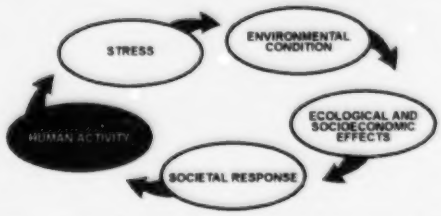
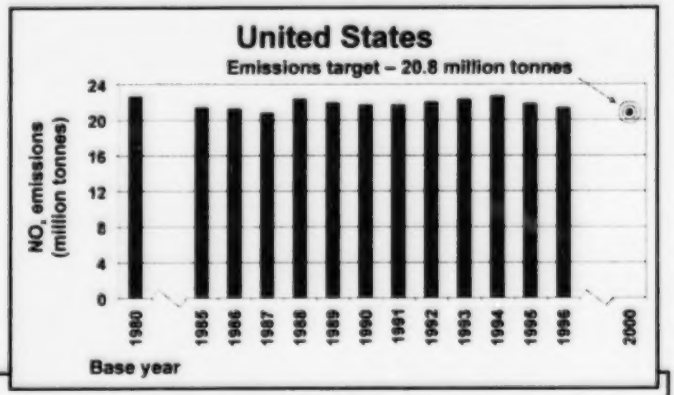
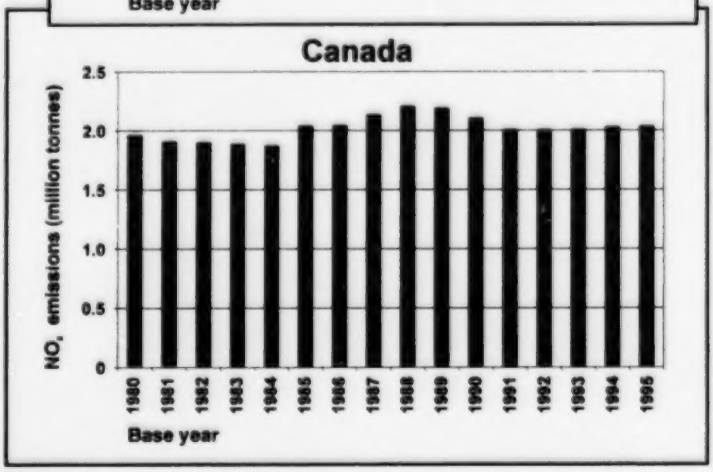


Acid Rain

Indicator: Emissions of nitrogen oxides

- In Canada, NO_x emissions remained around the 2 million tonne level over the 1991–95 period.
- Mobile sources (e.g., cars, trucks, rail, air, and marine transportation) accounted for 52% of total Canadian NO_x emissions in 1995, while stationary sources (e.g., power generation, industrial processing, commercial and residential combustion) accounted for the remainder.
- Total U.S. NO_x emissions fell by 4% between 1993 and 1996, from 22.3 million tonnes to 21.3 million tonnes.
- Canadian measures to reduce mobile NO_x emissions include more stringent performance standards on exhaust emissions from new vehicles, whereas measures to reduce stationary source emissions include emission limits for new fossil-fuelled power plants, retrofits at several existing power plants, and new standards for boilers, process heaters, and kilns.
- Under the Canada–United States Air Quality Agreement, Canada is committed to a 10% reduction in projected NO_x emissions (of 970 000 tonnes) from *stationary* sources by the year 2000. The United States must reduce its *total* annual NO_x emissions by approximately 1.8 million tonnes from the 1980 level by the year 2000.





Notes:

i) U.S. emission estimates (tons) have been converted to tonnes (1 ton = 0.91 tonnes).

ii) Canadian emission estimates are based on Canada's 1998 report to the United Nations Economic Commission for Europe (UNECE). They may differ from previously released estimates because of changes in methodology.

Canadian source:

Pollution Data Branch, Environmental Protection Service, Environment Canada.

U.S. source:

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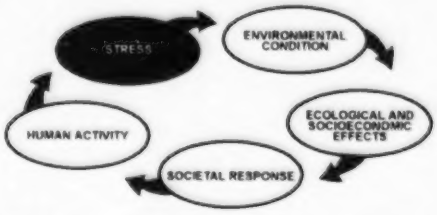
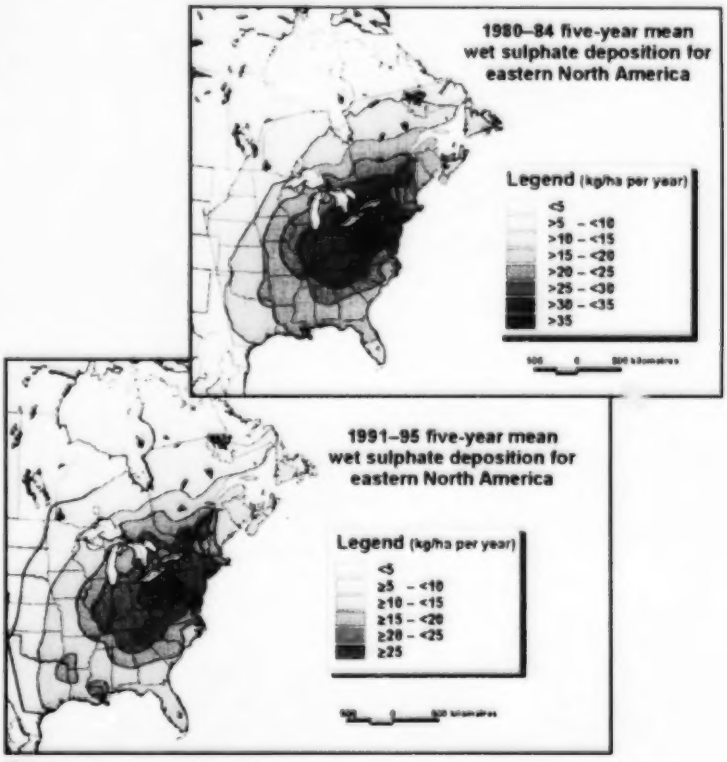


Acid Rain

Indicator: Wet sulphate deposition

- The area in eastern Canada receiving 20 kg/ha per year or more of wet sulphate deposition declined by 61% between the two five-year periods, 1980–84 and 1991–95, reflecting the reduction in SO_2 emissions in both Canada and the United States.
- The 20 kg/ha per year wet sulphate deposition target was established as an interim objective in the 1980s. Recent research confirms that this target is too high, as 20 kg/ha per year exceeds the buffering capacity of many acid-sensitive lakes in eastern Canada.
- Emission changes combined with variations in precipitation and weather patterns cause changes in the shape and size of the yearly deposition patterns. Thus, emission reductions may not be immediately translated into deposition reductions.


1980–84 five-year mean wet sulphate deposition for eastern North America
Legend (kg/ha per year)
<5
>5 – <10
>10 – <15
>15 – <20
>20 – <25
>25 – <30
>30 – <35
>35
1991–95 five-year mean wet sulphate deposition for eastern North America
Legend (kg/ha per year)
<5
≥5 – <10
≥10 – <15
≥15 – <20
≥20 – <25
≥25

Notes:

i) Wet sulphate deposition is the weight of sulphate deposited to the earth's surface by precipitation and is an indicator of acid rain. The target value of 20 kg/ha per year of wet sulphate deposition was derived from limited data available in the early 1980s and was based mainly on sport fish loss, which occurs at a pH level of 5.3 and below. More recent studies suggest that a pH of 6.0 is needed to protect most aquatic organisms.

ii) The data presented here are for excess sulphate (or sea-salt corrected sulphate), i.e., the measured sulphate deposition minus sea salt-contributed sulphate.

iii) The National Atmospheric Chemistry (NAtChem) Database was used for the analysis of acid precipitation data.

iv) National figures on dry sulphate deposition are not available.

Source:

R. Vet, C.-U. Ro, and D. Ord, National Atmospheric Chemistry Database and Analysis Facility, Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

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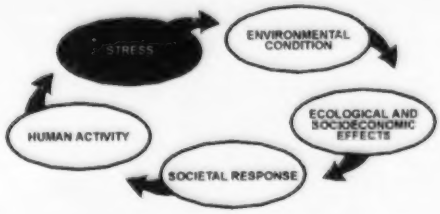
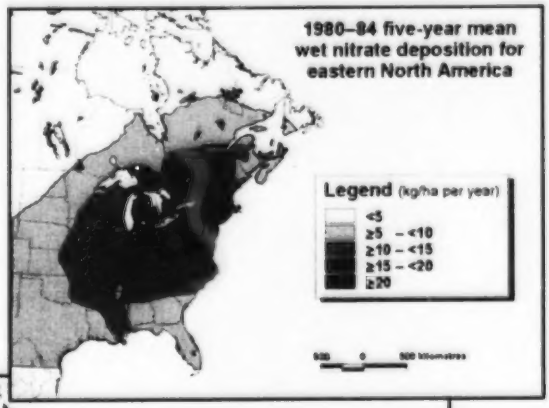


Acid Rain

Indicator: Wet nitrate deposition

- The pattern of wet nitrate deposition in Canada changed little between the two five-year periods, 1980–84 and 1991–95, reflecting the minimal progress in reducing NO_x emissions in both Canada and the United States.
- From 1991 to 1995, the areas in eastern North America receiving the highest wet nitrate deposition included southern Ontario and the lower St. Lawrence River in Canada and the Ohio–Pennsylvania–West Virginia and upper New York state regions in the United States.
- Nitrogen-based acidification is evident in many lakes scattered throughout southeastern Canada, particularly in south-central Ontario and southwestern Quebec. Concern exists that nitrogen-based acidification of some Canadian lakes may increase over time. This could undermine the ecological benefits expected to result from SO_2 emission reduction.
- Changes in the shape and size of the yearly deposition patterns are largely due to variations in precipitation and weather patterns.



Notes:

i) Wet nitrate deposition is the weight of nitrate deposited to the earth's surface by precipitation and is an indicator of acid rain.

ii) The National Atmospheric Chemistry (NAtChem) Database was used for the analysis of acid precipitation data.

iii) National figures on dry nitrate deposition are not available.

Source:

R. Vet, C.-U. Ro, and D. Ord, National Atmospheric Chemistry Database and Analysis Facility, Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

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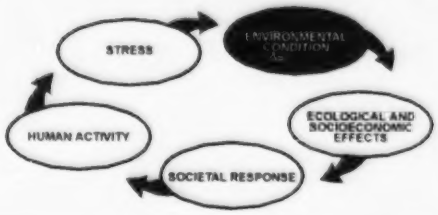
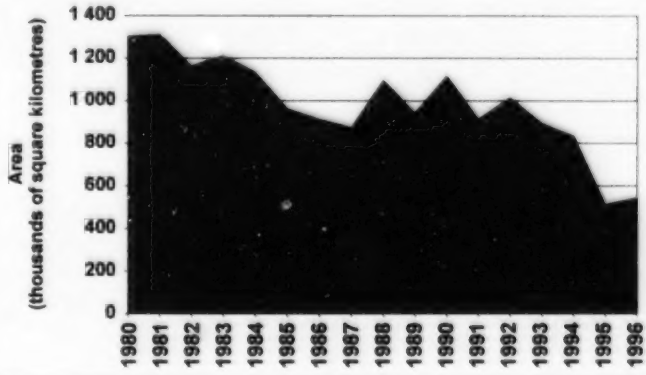


Acid Rain

Indicator: Area of exceedance of wet sulphate deposition above critical loads

- The area in eastern Canada receiving wet sulphate deposition in excess of critical loads for aquatic ecosystems declined by over 40% between 1991 and 1996, from about 910 000 to about 540 000 square kilometres.
- The critical load for aquatic ecosystems is the amount of wet sulphate deposition that must not be exceeded in order to protect at least 95% of lakes in a region from acidifying to a pH level of less than 6.0. Many studies suggest that a pH of at least 6.0 is needed to protect most aquatic organisms.
- Scientists predict that large areas in eastern Canada, encompassing tens of thousands of lakes, will continue to receive wet sulphate deposition above critical load limits for aquatic ecosystems, even after the Canadian and U.S. SO_2 emission controls are fully implemented in the year 2010.

Eastern Canada: Area receiving wet sulphate deposition in exceedance of critical loads



Notes:

i) The National Atmospheric Chemistry (NAtChem) Database was used for the analysis of acid precipitation data.

ii) Exceedance is the term used to describe the difference between the annual deposition and the "critical load" at any given location. The area of exceedance represents the sum of the areas experiencing exceedances.

Source:

R. Vet, C.-U. Ro, and D. Ord, National Atmospheric Chemistry Database and Analysis Facility, Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

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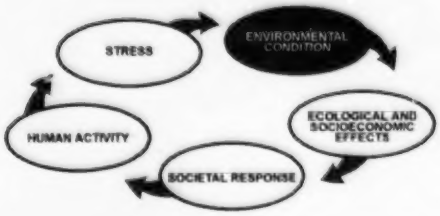
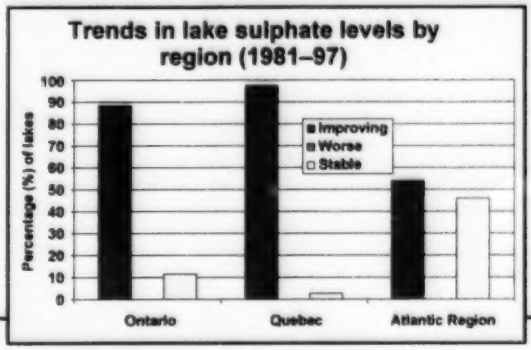
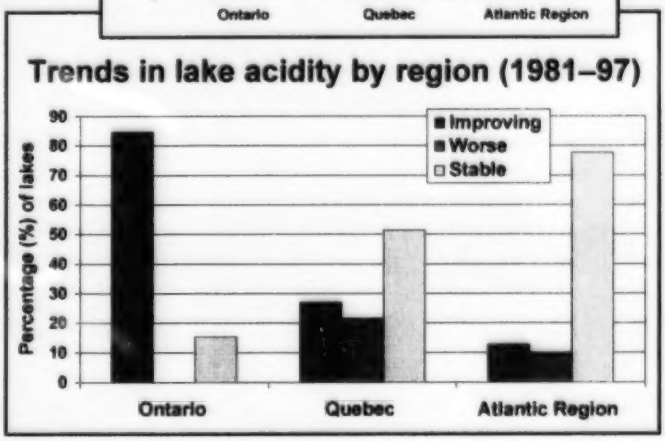


Acid Rain

Preliminary Indicator: Trends in lake acidity in southeastern Canada

- Of 152 lakes monitored for acid rain effects in Ontario, Quebec, and the Atlantic Region between 1981 and 1997, 41% showed some improvement in acidity. Acidity levels were stable in 50% of the lakes and became worse in 9%.
- Seventy-three percent of the monitored lakes in Ontario are in the Sudbury region. Improvements in most of the lakes in the Sudbury area can be attributed to the substantial control of SO_2 emissions from local nickel smelters. Despite significant SO_2 controls in all of eastern Canada, the acidity of most lakes in the remainder of Ontario, and in Quebec and the Atlantic Region shows little change partly because of the continuing transboundary flow of acidifying emissions from the United States.
- Lake sulphate levels are indicators of the primary acidifying agent (sulphuric acid) in acid rain. Sulphate levels are declining in most lakes in Ontario, Quebec, and the Atlantic Region.
- Lake sulphate levels respond to a reduction in SO_2 emissions. A time lag of many years is possible before this translates into widespread regional improvements in lake pH or alkalinity. There is a further time lag before these improvements are likely to result in changes to populations of fish and other biota.





Notes:

i) For acidity: Increasing pH or alkalinity implies an "improving" condition, decreasing pH or alkalinity implies a "worse" condition, no trend means "stable".

ii) For sulphate: Decreasing levels imply "improving", increasing levels imply "worse", no trend means "stable".

iii) Number of Lakes: Atlantic Region, 63; Quebec, 37; Ontario, 52.

iv) Atlantic Region refers only to the provinces of Nova Scotia and Newfoundland.

v) Most of the data sets spanned the period from 1981 to 1996–97. However, some data sets began in 1983.

Sources:

Atlantic Region: T.A. Clair, Environment Canada. Quebec: A. Kemp, Environment Canada. Northwestern Ontario: M.P. Stainton, Fisheries and Oceans Canada. Algoma: D.S. Jeffries, National Water Research Institute. Sudbury: W. Keller, Ontario Ministry of Environment. Muskoka/Haliburton: P.J. Dillon, Ontario Ministry of Environment.